Exploration for Saltwater Supply for Shrimp Aquaculture, Puerto Penasco, Sonora, Mexico

EXPLORATION FOR SALTWATER SUPPLY FOR SHRIMP AQUACULTURE, PUERTO PENASCO, SONORA, MEXICO

by

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ABSTRACT

The University of Arizona's Environmental Research Laboratory, with the Universidad de Sonora, has operated a research station at Puerto Peñasco, on the northeastern Gulf of California, since 1962. Controlled-environment shrimp aquaculture, the Laboratory's most recent research interest, requires a large, dependable supply of filtered, temperate seawater. A University Water-Supply Study Team explored for a supply in an 850-hectare site near the Estero Marua for a proposed ten-hectare shrimp farm. The study included geological, geophysical, and hydrological investigations, and consideration of groundwater, Gulf, estuarine, and combined seawater sources. A thick, fine sand, in the study area, has a very low permeability, contains highly saline water, and could sustain low yielding wells. A thin, coquinoid beachrock, along the Gulf coast near the study area, has a high permeability, contains seawater, and could sustain high yielding wells. Gulf and estuarine water sources have unacceptable temperature ranges, though they could be utilized if mixed with groundwater, stored, and insulated. Recommendations include: drilling, testing, and analysis of coquina; modeling of groundwater heat flow, water-quality effects, and potential well-field designs and impacts for beachrock development; analyzing well design and performance; relaxing temperature and salinity constraints; reusing aquacultural wastewater; and reducing water demand.

INTRODUCTION

A water-supply feasibility study for shrimp aquaculture at Puerto Peñasco, Sonora, Mexico, was undertaken in July 1978 at the request of the Environmental Research Laboratory (ERLAB) of the University of Arizona. Carl N. Hodges, Director of the Laboratory, appointed Lee Mahler as Project Coordinator in Tucson, and Fausto Soto as Site Coordinator in Puerto Peñasco.

A University Water-Supply Study Team was established by the University's Water Resources Research Center (WRRC). Sol D. Resnick, Director of the Center, was Project Advisor. The principal investigators of the study team are this paper's authors. They assembled over 30 others to provide technical support, and assist in the field and laboratory.

The Laboratory, with the Universidad de Sonora, has operated a research station (Unidad Experimental Peñasco, U.E.P.) at Puerto Peñasco, on the northeastern Gulf of California, since 1962. Solar seawater distillation, greenhouse vegetable agriculture, controlled-environment shrimp aquaculture, and halophyte cultivation have been the Laboratory's research interests in Peñasco. Recent interest in aquaculture requires a large, dependable supply of filtered, temperate seawater. Riley and Percious (1974) and Percious (1976) described the local hydrogeology and assessed the feasibility of water-supply expansion near the U.E.P.

An 850-ha site, north and west of the west arm of the nearby Estero Marua, was selected by the Laboratory as a potential aquacultural site requiring large amounts of seawater (Figure 1). The Water-Supply Study Team explored for a suitable salt-water supply in and near this site. This paper summarizes that exploration activity, and more recent work conducted by the Laboratory.

EXPLORATION METHODS

Exploration methods include those required for geological, geophysical, and hydrological investigations.

GEOLOGICAL METHODS

Geological methods include field studies in the study area, beachrock studies at selected coastal and estuarine localities, laboratory examination of well cuttings and pit and soil samples, analysis of maps and aerial photographs, and review of existing geological data.

GEOPHYSICAL METHODS

Geophysical methods include shallow seismic refraction profiling for water-table and beachrock mapping, deep explosive-source seismic refraction techniques for subsurface stratigraphic and bedrock topographic mapping, earth resistivity methods to locate water-quality interfaces, and gravity and magnetic surveying to estimate depth to bedrock.

HYDROLOGICAL METHODS

Hydrological methods include exploration, mapping, and evaluation of groundwater, Gulf, estuarine, and combined seawater sources. Slim-hole test-well drilling (Figure 1), Gulf data, estuarine profiling, and conjunctive-use analyses were performed. Previous data were reviewed, and results of geological and geophysical investigations were synthesized and incorporated. Limited hydrologic modeling, graphical data analysis, and relative alternative cost considerations were completed.

EXPLORATION RESULTS

The complete results of this study were presented to the Environmental Research Laboratory as a three-volume report (Water-Supply Study Team, May 1979). The following is paraphrased from that report.

The study area has a dry tropical, warm desert climate, and is part of a young, neotrailing edge coast of the Gulf of California. Soils are recently formed, without developed profiles. Vegetation is desert, intertidal, and marine. Hydrology is controlled by low rainfall and high tidal pulses, though older inland sea levels and evaporating basins influence current groundwater.

Surficial geologic units include a Pleistocene aged coquinoid beachrock (coquina) along the Gulf coast, Recent beach and dune sands, and estuarine deposits. Subsurface geologic units in the region include Peñasco basalt, the coquina, Estero sand, Cerro Peñasco regolithic conglomerate, and a Mesozoic aged granitic bedrock. Subsurface units in the study area include the coquina, Estero sand, and granitic bedrock.

The Gulf of California is subject to the second highest tides in North America. The Estero shows the same tides with distortion. The maximum surface-water volume in the western arm of the Estero Marua is about nine million cubic meters. Though the water supply in the Gulf and Estero is essentially infinite, seasonal temperature variations reduce its potential supply for intensive shrimp aquaculture.

A thick, fairly uniform, fine sand (0.16 mm), the Estero sand, occurs in the study area. It is at least from 460 to 490 m thick, comprises a water-table aquifer, has a very low permeability (4 m/day), and contains highly saline groundwater. Relatively deep, low yielding, 6.3-lps wells are possible in the Estero sand.

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thick, comprises a water-table aquifer, has a relatively high permeability, and contains seawater. Relatively shallow, high yielding, 63-lps wells are possible in the coquina.

CONCLUSIONS

Conclusions are based on consideration of water-quantity and quality requirements, and what was found in the study area.

1. Inland groundwater development is limited by low permeabilities, high salinities, and potential well-completion and land-subsidence problems. Artificial recharge is likewise restricted.

2. Coastal groundwater development is possibly sufficient for a ten-hectare facility if a long enough stretch of land is available.

3. Combined use of surface-water and groundwater sources is possible if surface waters can be stored and insulated.

4. If appears infeasible to meet the ten-hectare requirements in the study area without groundwater contribution.

5. Engineering water-supply costs are lowest with increasing groundwater contributions.

RECOMMENDATIONS

The following hydrological recommendations are made:

1. Drill large-capacity, deep, production-test wells in the study area and along the Gulf coast for detailed logging, sampling, aquifer test, and analyses. This is needed to obtain better estimates of aquifer properties, water quality, and well performance, in addition to deeper and more comprenhensive lithologic and hydrologic information.

2. Mathematical modeling and analysis of groundwater heat flow, water-quality effects, and potential well-field designs and impacts for beachrock development.

3. Engineering analysis and field testing of various methods of well design, completion, and development to increase future well performance.

The following management recommendations are made:

1. Conduct a hydrological investigation along a Gulf coastal strip in the beachrock zone adjoining the U.E.P. The strip should extend at least 1500 m along the shore and a least 150 m inland.

2. Relax water-quality constraints on water supply.

3. Reduce new seawater demand.

4. Treat and reuse aquacultural wastewater.

MORE RECENT WORK

A second study phase was completed (Popkin, 1979, 1980a) by the Environmental Research Laboratory. This phase combined the first hydrological and management recommendations. Five well sites were evaluated, one near the Shipwreck in the 850-ha study area, and four along the coastal strip east of the U.E.P. (Figure 2). A 6-in. direct rotary supply and observation well, and a nearby 16-in. reverse circulation test-production well, were completed at each site.

Results showed the following:

1. Coquina was absent, but a thin, non-extensive alluvial gravel was found near the Shipwreck. Large-scale groundwater development cannot be maintained in this material which contained highly saline water.

2. About seven meters of coquina, with an average particle size of 2.0 mm, was found in the Gulf coastal wells, 240 m inland. This water-table aquifer is highly permeable (180 m/day), and contains seawater.

3. Recharge from the nearby Gulf guarantees a continuous seawater source to potential well fields along the Gulf coast.

4. The coquina aquifer along the Gulf coast can sustain 63-lps wells, with current methods, and likely greater than 95-lps wells with improved methods.

Phase II conclusions are that 36 ha of aquacultural development are possible, if all coastal land were available, from a well field paralleling and within 90 m of the Gulf. If about 3050 m of coastal land were available, which appears likely, a filtered, temperate seawater supply could support 12 aquacultural hectares from a similar well field.

Recommendations from this recent work include continued well-performance improvements, inland drilling from the coast to determine inland extent of coquina, and mathematical modeling. Hopefully, these activities will comprise a third water-supply study phase. Concurrently, well and well-field designs are being evaluated. These designs are discussed in an accompanying paper to these proceedings (Popkin, 1980b).

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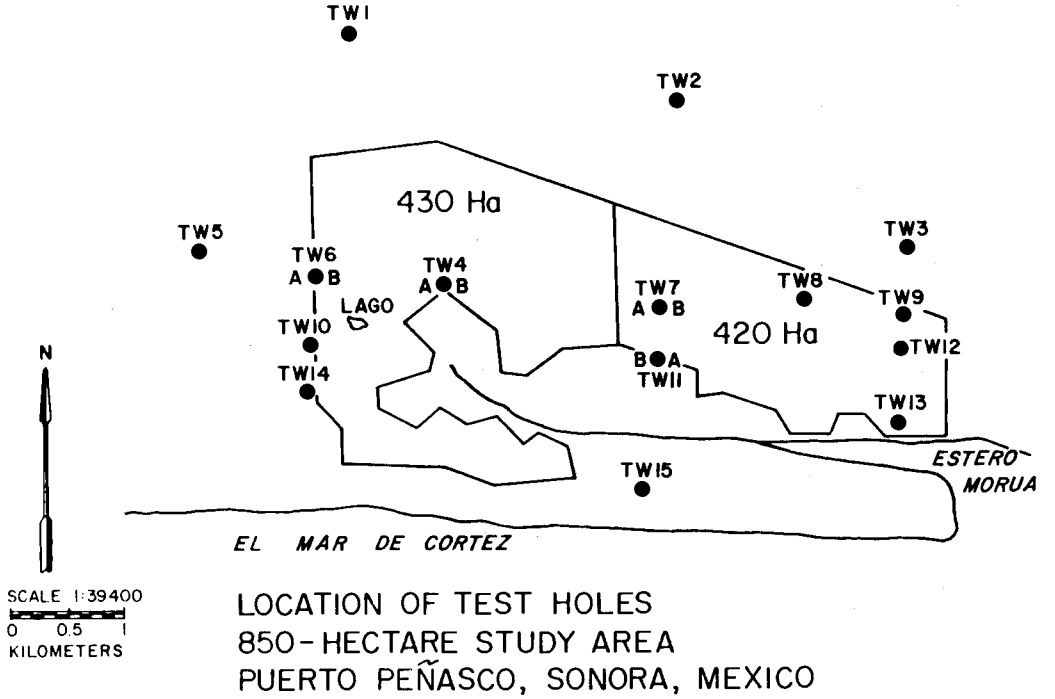
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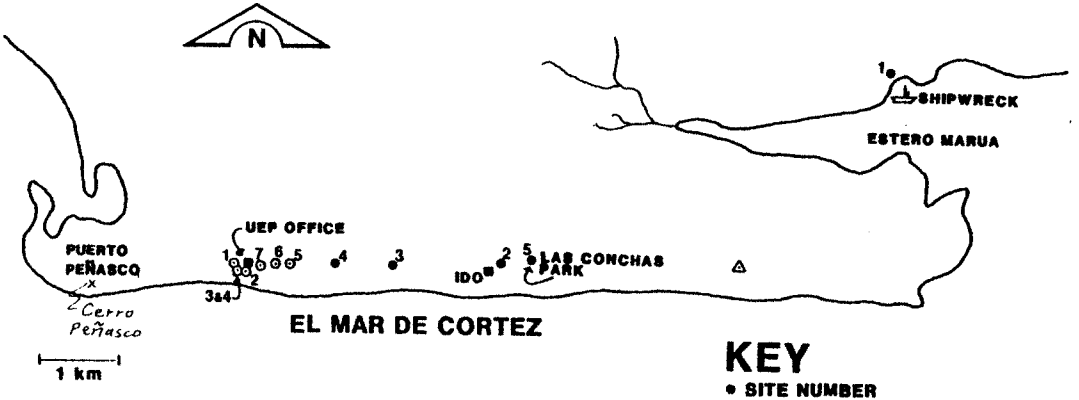
LOCATION OF TEST HOLES
850-HECTARE STUDY AREA
PUERTO PEÑASCO, SONORA, MEXICO

Figure 1.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KEY
SITE NUMBER
ERL WELL NUMBER
ABANDONED LAS CONCHAS WELL-16
LOCATION OF TEST SITES
PRODUCTION-Test well drilling program
Puerto Peñasco, Sonora, Mexico

Figure 2.